A Platform For Adaptive Processing In Machine Tool Vibration Monitoring

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Motivation

- Deployable signal conditioning
- Deployable signal processing
- Local data bandwidth reduction
- Process vibration data to usable information
- Interface dynamic sensors to infrastructure
- Reduce cost of sensor deployment

Motivation

- Add Dynamic Measurements To Industrial Capabilities
- Remove Traditional Barriers
  - Cost
  - Physical Packaging
  - Network Bandwidth
- Ultimately Empower:
  - Machine Health
  - Tool Wear
  - Part and Process Quality

Traditional Architecture

- Transplant FFT Analyzers
  - Technological Overkill
- PC Board DAQ
  - Significant Engineering Up Front
  - Deployment Issues For Multi-channel

Distributed Architecture

- Integral ICP® signal conditioning
- High resolution 24 bit delta-sigma ADC
  - 96 kHz Bandwidth
- IEEE P1451.4 TEDS sensor support
- Isolated digital inputs & outputs
- Network support
- Programmable DSP
- Local non-volatile program and data storage
- Real-time and time of day clocks

Distributed Architecture

- Sealed NEMA 4 Enclosure
- No Ventilation Required
- < 4 Watts @ 24VDC
- Memory: 32 MB DRAM (5 Minutes of Time History @ 5 kHz)
- Bolt On
- Tamper Proof

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Adaptive Processing Application

- Single Spindle Transfer Lines
- Detect Significant Change In Process
  - Tool Faults (loose, broken, or missing)
  - Bearing Failures
- Minimal Configuration Effort

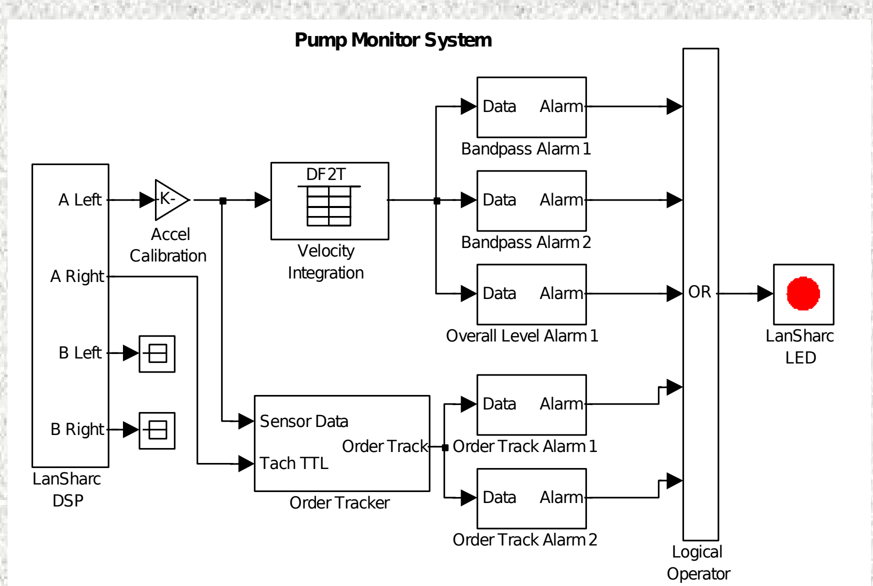
Application Development

- Prove application using traditional tools
  - FFT analyzer
  - PC based data acquisition
  - Record Actual Plant Data
- Develop Algorithms in Lab Environment
  - Write "C" code
  - Matlab® / Simulink® / Stateflow®

DSPdeveloper + LanSharc

Use Simulink® to program custom applications by drawing block diagrams.

DO THIS!



NOT THIS!

```
#include "pump_mon...
#include "pump_mon.prm"

/* user code (top of source file) */
int cp_valr0aPing,cp_valr0aPong;
segment("DMA_Buffer") volatile int_T Ping0AR [2*(int)256.0];
segment("DMA_Buffer") volatile int_T Pong0AR [2*(int)256.0];

/*
 * chaining pointers for ping/pong buffering
 */
segment("DMA_Buffer") _tcb rx0a_tcb[2] ={
  {0, 0, 256.0*2, 1, 0},              /* Ch 1 & 2 transmit tcb */
  {1, 0, 256.0*2, 1, 0}};              /* Ch 1 & 2 transmit tcb - set GP reg */

/* model step function */
void pump_mon_step(int_T tid)
{
 /* local block i/o variables */
 real_T rtb_root_Alarm_Level[100];
 real_T rtb_root_Binary_Comparison;
 real_T rtb_s4_Multichannel_IIR_Fi[256];
 real_T rtb_temp12[256];

 /* update absolute time */
 if (ssIsSampleHit(pump_mon_rtO, 0, tid)) {
  ssUpdateRealAbsoluteTime(pump_mon_rtO);

  if (ssIsSpecialSampleHit(pump_mon_rtO, 1, 0, tid)) {
   ssUpdateSubrateTaskTime(pump_mon_rtO, 1);
  }
 }

 if (ssIsSampleHit(garbage2_rtO, 1, tid)) { /* Sample time: [2.5666666666666669E+000,
0.0] */
  /* Constant Block: <Root>/Alarm Level */
  {
   int_T i1;
   real_T *y0 = &rtb_root_Alarm_Level[0];
   const real_T *p_root_Alarm_Level_Value = &garbage2_P.root_Alarm_Level_Value[0];

   for (i1=0; i1 < 100; i1++) {
    y0[i1] = p_root_Alarm_Level_Value[i1];
```

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Simulink Block Diagram to Application

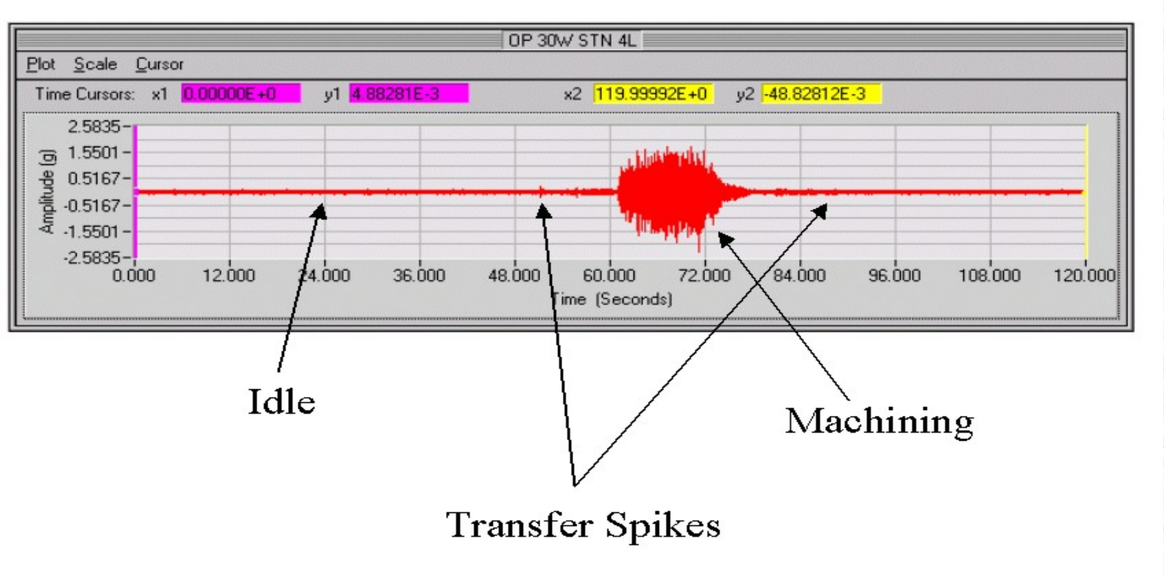
- SDL’s DSPdeveloper enables nonprogrammers to develop custom “smart” applications.
- Develop, simulate and debug in Simulink.
- Compile, link and download bootable, stand-alone applications to flash memory with a single mouse click using DSPdeveloper.

Application Development

- Port Algorithms To LAN Sharc
  - Prove Hardware By Processing Canned Data
- Deploy Pilot Project

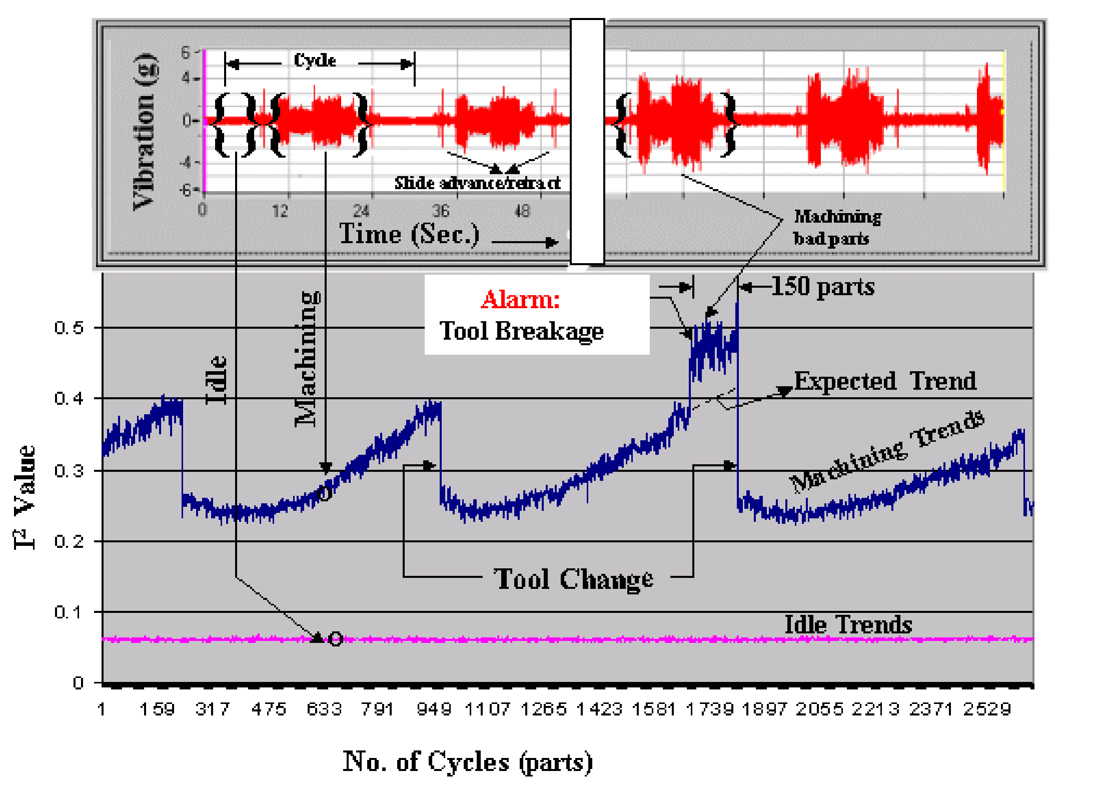
Application Development

- Laboratory Algorithm Development
  - Cycle Detection



Application Development

- Laboratory Algorithm Development
  - Apply Operation Specific Criteria

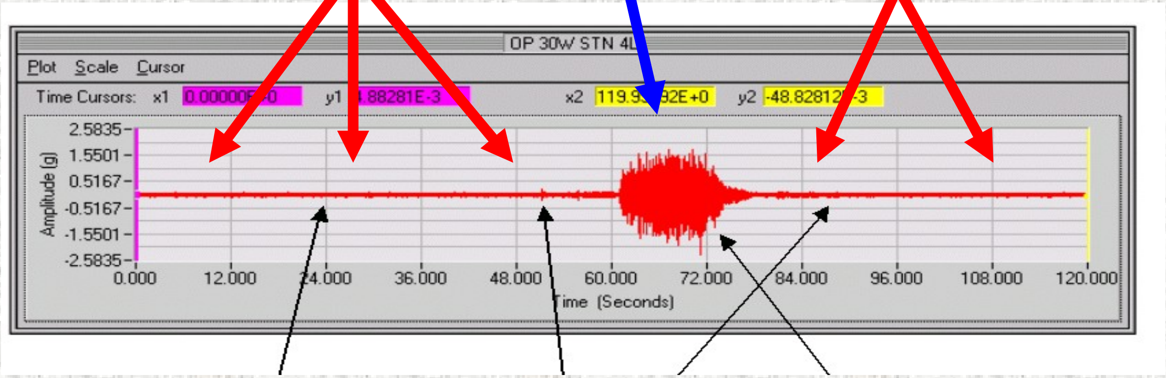


Adaptive Processing

- Alarm Criteria Based On Normalized Distributions
  - Algorithm is 'Seeded' With 20 Machining Cycles of Known 'Good' Quality
  - Statistical Distributions Are Then Found In 'Learn' Mode
  - Finally, 'Test Mode' Applies The Established Criteria

Test Mode

- Evaluate Both On-Cycle and Off-Cycle Parameters



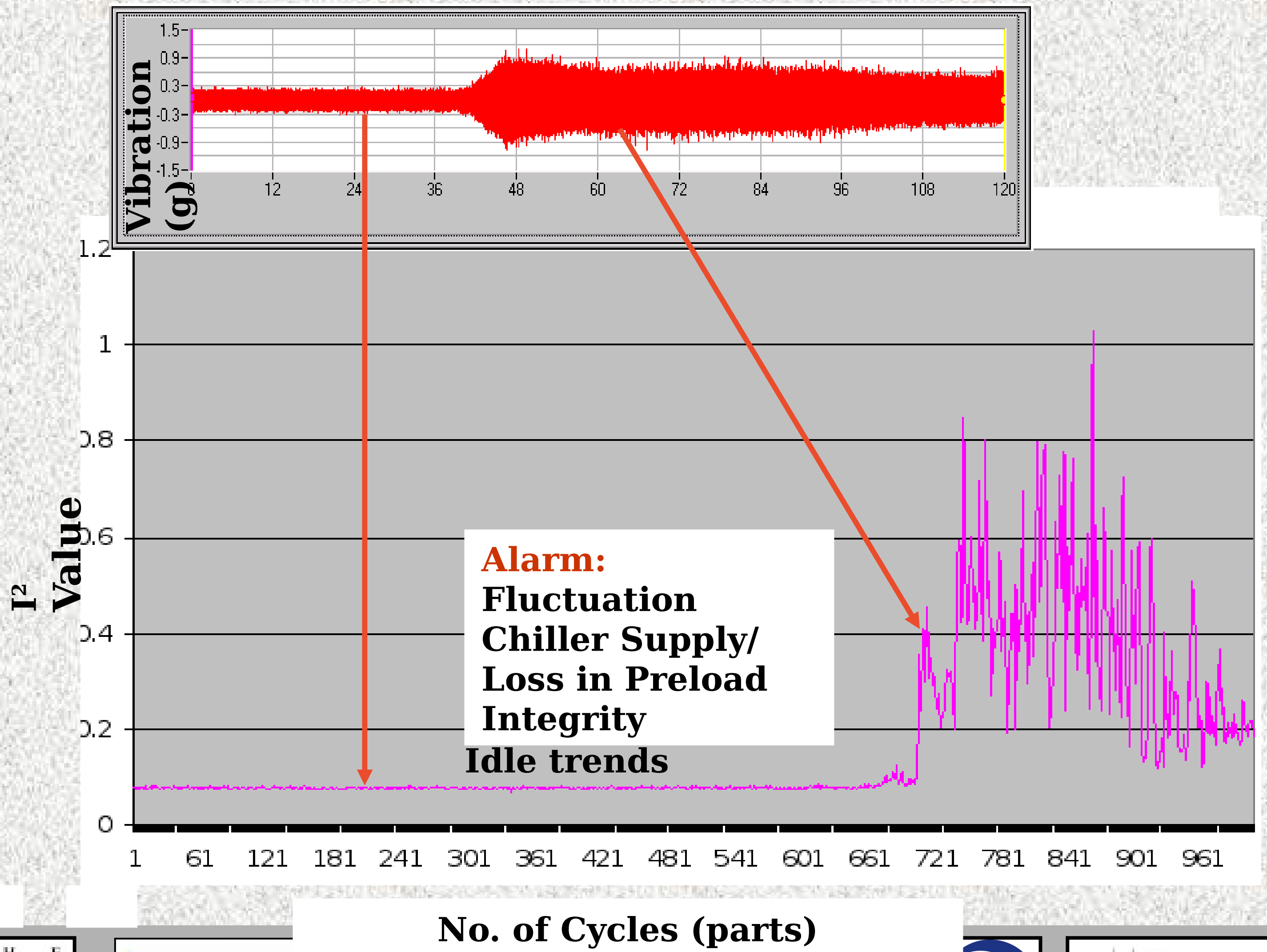
Problems Detected

- Sources of 'Off-Cycle' data Alarms
  - Spindle Bearings
  - Tool Balance
  - Impacts occuring during idle
  - Spindle Preload

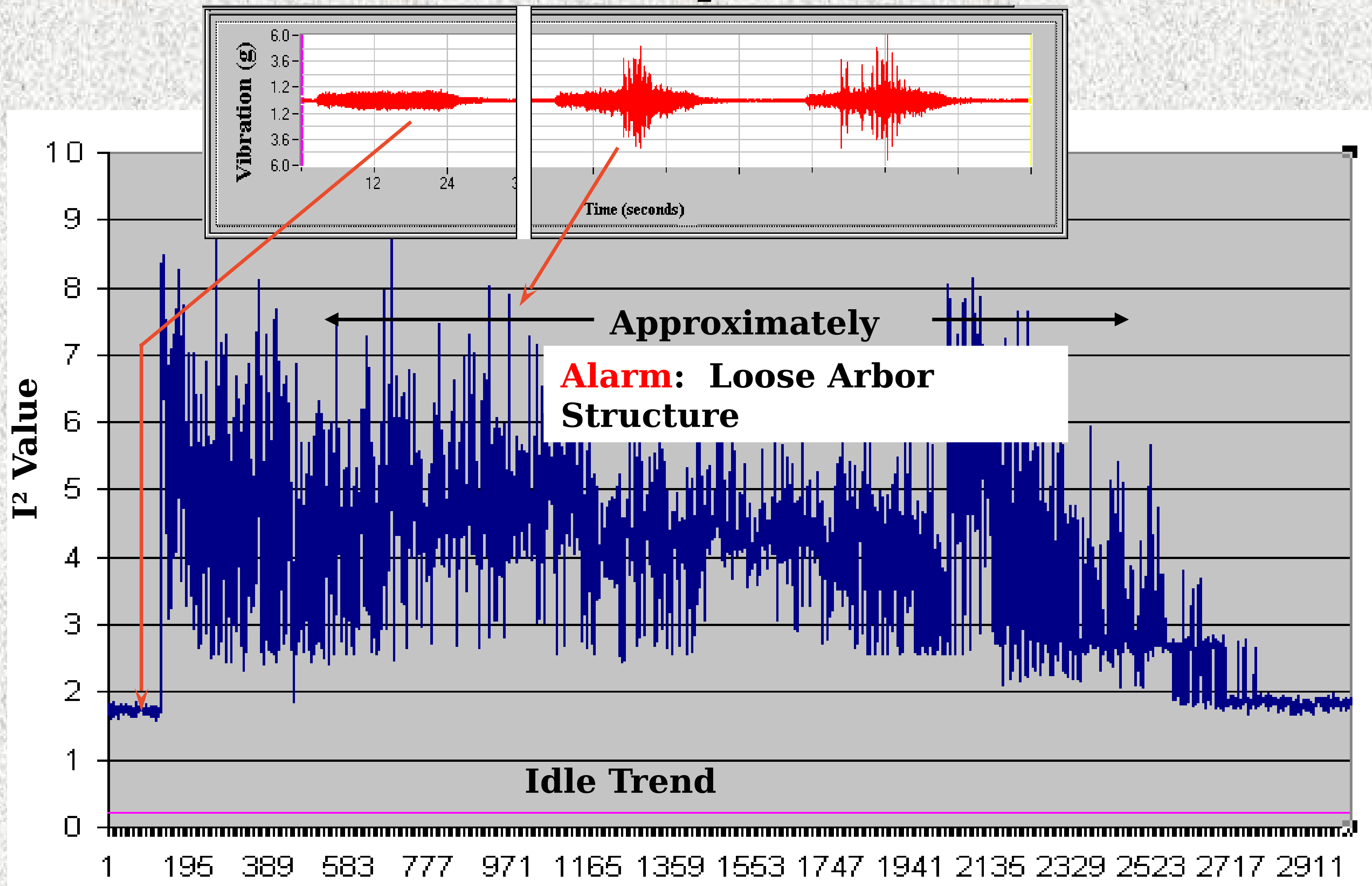
Problems Detected

- Sources of 'On-Cycle' data Alarms
  - Broken or Worn Inserts
  - Workpiece Material Problem
  - Workpiece Clamping Problems

Off-Cycle Alarm - Spindle Preload



On-Cycle - Loose Arbor (Sawing Op)



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On-Cycle Detection - Soft Workpiece